An Evaluation of Current Status of Renewable Energy Sources in India

Sunil Kumar, Manish Kumar Rawat, Sanjeev Gupta

Abstract*: *Many people in rural society of India does not have access to natural energy resources like LPG , electricity as there is no facilitation of grid erection. Hence it becomes imperative for country like India to go for renewable energy resources as alternative to conventional energy resources. This paper evaluations the potential of different sources of renewable energy in India. It also highlights the trends in the growth of renewable energy sector, although at the same time shows that there is need of a hybrid renewable energy model for rural electrification in India. Paper also shows the scope in using the agriculture waste as bio fuel which burned otherwise and prompt health hazards besides environmental pollution, also describing many technologies which are in the demonstration stage like Tidal, OTEC, Solar thermal power plants. Many constraints put development in the field of solar and wind sector, on hold like availability of solar rays throughout the year . The main aim of the paper is to evaluation all possible options in renewable energy sector so that large segment of rural population can have access to electricity and to meet their basic energy needs.

Index Terms*: *Renewable energy, Tidal energy, hybrid renewable energy, bio fuels etc.

I. INTRODUCTION

Energy has been the backbone of human civilization since time immemorial & its desire is increasing gradually with increase in population, industrialization, economic growth all around the world. Conventional fuel based power generation and rapid increase in population are resulted in a major challenge before the mankind also it leads to the danger of CO_2 which is already beyond the alarming level**.** Business & trading are expanding readily, but our fossil fuel sources are diminishing. The replenishment rate of energy is increasing which slowly giving rise to the biggest threat to humanity & nature that is climate change **[sanjeev et al 2017].** The fact which is of high concern is the addiction to fossil fuel-based energy resources, which still serves over 85% of world's energy need & is deeply instilled in our modern societies. Consumption at this rapid rate will not meet our present or future energy requirement and we will be running out of fossil fuels.

1.1 Indian energy scenario

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India is in a censorious spot, due to its high population growth, economic growth, civilization, industrialization, up gradation in per capita utilization of electricity, exhaustion of coal reservoirs, hike in coal, crude oil import. Amongst the Global powers, India stands at 7th position in the world GDP wise and as per purchasing capacity it stands at 3rd position after China and America this is as per International Monetary Fund World Economic Outlook (IMF-WEO) April 2015. India holds 9th rank as per the real GDP growth (%change). Population of India has reached 1.34 billion till June 2, 2017 **(estimated by united nation department of economic & social affairs)** & there is a prediction that it will take over china by 2030 in terms of population. From 2000 to 2012, the energy demand has reached to about 770 million tons from 450 million tons of oil equivalent (toe) & it is anticipated that it will be at 1250 to 1500 million toe in 2030 (Integrated Energy Policy Report).

On 02, Aug 2017, there is news in The Times of India (Delhi**) "Earth likely to warm over 2 degrees by 2100"**. The world will almost certainly reach a tip point and will have catastrophic effects due to climate change, as per an evaluation is carried out. Its indeed an alarming level which will lead disastrous effects like widespread drought, India's summer monsoon is very unlikely in its prediction, leading to a downfall in crop production, loss extreme weather and dangerous increase in sea level.

Sole opportunity is under way of RE sources to sort out the problem of energy ingress in India **[Garg P (2012)].**RE sources have that potential to lessen the out pouring of greenhouse gases from conventional fossils there by alleviating the climate change **[Edenhofer et al. 2011].** An effort is required for a changeover from fossil based power to renewable in order to abstain from extended energy block off. RE resources are the only promising & prospective way to reduce these emissions & to cope up with future energy needs of both developed & developing countries **[A report by WWF India and The Energy and Resources Institute 2013].** RE technologies are often believed to be a scrubbed source of energy and right proportion use of which actually have less stressed environmental impact, produce a low proportion of subsidiary waste and more importantly are sustainable resource as per present and future social and economic aspects.

Renewable energy sources restock it selves naturally without being a chance of getting exhausted in the earth. The major types of renewable energy sources with their applications are shown in **Table 1.1.**RE technologies have an exceptional trait in alleviating greenhouse gases emission and thereby reducing global warming by becoming an alternate to traditional energy resources (fossil fuel based) **(Panwar, Kaushik, & Kothari, 2011).**

The Government of India has been formulating various policies in this sector for its promotion. It includes preferential charges, income tax rebate, banking facilities like easy loans, capital and interest at nominal rates, renewable purchase obligations and renewable energy certificates **[IREED. 2015].** Incentives are motivating/boosting up the energy sector for adoption of RE but two critical aspects which are actually hindering its adoption is its distribution network & development of advanced storage technology **[Wee et al 2012].**

Table 1. R E Sources & their usage (Panwar et al., 2011)

Energy sources	Applications
Hydro power	Electric Power generation
biomass	power generation, gasification, digestion
Geothermal	Urban heating, hydro thermal
Solar	Solar domestic systems, dryers, solar cookers
Direct solar	Photovoltaic, thermal power generation, solar water heaters
Wind	windmills, water pump
Wave and tide	design, tidal stream

With the objective of energy independence, RE sources has to be developed to such an extent so that reliance on imported oil can be marginalized . Compared to developed countries, per capita energy consumption in India is still far below the considerable level. Nevertheless, the average per capita energy consumption is to rise steeply due to boost in the economic and industrialization aspects. The reliable renewable energy can be an important link in boosting our industrialization.

II. 2. LITERATURE EVALUATION

2.1 Current energy scenario of India

In 2013, India ranked at 3rd place in the world in electric power producer with 4.8% share worldwide in electric power generation well ahead of Russia and Japan but is still lagging behind in power generation **[Source:http://en.wikipedia.org/wiki/Electricity sector in India].** Inspite of rise in electric power generation, country remains in brawl in energy sector. During the year 2014-15, energy crisis of 5.1% is expected **[CEA, load Generation B alance report 2014-15].** Asian economy grows, the electric ity demand rises as there is an interrelationship between economic growth and electricity demand . India is putting continuous and considerable efforts to increase its power generation capability . Nevertheless, requirement for energy outstrips the supply more often. Table given below here shows various regions' installation capacity of generating power from various conventional and non conventional sources.**(Table 2.1).**

Table 2.1

Region	Mode wise breakup I			
	Thermal			
	Coal	Gas	Diesel	Total
Northern region	39481.0	5331.26	12.99	44825.25
Southern region	27382.50	4962.78	939.32	33284.60
Western region	58859.51	10915.41	17.48	69792.40
Eastern region	26527.88	190.00	17.20	26735.08
North-eastern region	60.00	1571.80	142.74	1774.54
Island	0.00	0.00	70.02	70.02
All India	153570.89	22971.25	1199.75	177741.89

Mode wise breakup II			
Nuclear	Hydro (Renewable)	RES (MNRE)	Grand Total
1620.0	16598.11	5935.77	68979.13
1320.0	11398.03	13784.67	59787.30
1840.0	7447.50	11271.07	90350.97
0.00	4113.12	432.86	31281.06
0.00	1242.00	256.67	3273.21
0.00	0.00	11.10	81.12
4780.0	40798.76	31692.14	253389.48

Source

http://www.cea.nic.in/reports/monthly/inst_capacity/Nov.14.pdf]].

Surprisingly even today, India has seventy five million households with no access to electricity. Looking at the current status India's power sector is likely to depend on coal outsourced till the year 2030 **[India's Climate Policy, interim report, January, 2015].** In spite of huge coal reserves, the percentage of imported coal in the country has been risen considerably which may rise to 30% in the upcoming years .**[www.ceew.in/pdf/natural Gas %, June 2014].** The liquified gas import is also expected to rise from 25% to huge 60% by the year 2035 to match as many as the 4 times rise in the energy demand by then **[Energy Statistics 2014].**

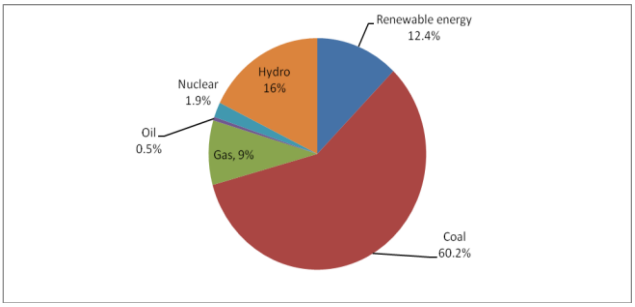

Fig 2.1: Source wise break-up of power generation in India (Source: MNRE, March, 2015)

2.2 Types of Renewable Energy Sources available in India

To generate renewable energy its sources are taken from natural processes that are refilled regularly over a period of time . Various forms of RE derives from SUN either directly or indirectly or can be obtained by heat that generates deep inside the earth. Renewable energy in its various forms are solar photo voltaic, solar, wind, tide, wave, ocean, biogas, geothermal, solid and liquid bio fuel, renewable municipal waste and hydro electricity.

2.2.1 Solar

Solar energy from sun is a surplus , free of cost and non polluting source of energy, but is still under utilized in India**[Azadian F, Radzi MAM, 2013, Veeraboina P, Ratnam GY, 2012].** Solar energy is available in two forms i.e. direct forms as solar rays and indirectly as wind, biomass, hydro and ocean energy etc. **[Kumar A et. al, 2010].** Many developing countries have great potential of utilizing solar energy emmited from Sun **[Mirza UK et. al, 2003]**. As per the data available in 2013, solar energy accounted for only 0.8 per cent of total power generation in India. India being a tropical country which receives sunlight around three hundred days in a year. Academically studied , India receives an amount of solar energy on its land area which is about 5000 trillion KWh per year (or 5Wh/yr) **[Muneer et al. 2005].** Intensity of solar rays that reached the earth surface has range of 0.06–0.25 kW/m^2 from highest to lowest latitudes **[Timilsina GR et. al 2011].** Average temperature in India is in the range of around 28^o C which makes India a fine candidate of electric power generation from Sun rays **[Sahoo SK, 2016].**

India has sufficient solar energy because of its geography which lies between 8°4'to 37°6'north latitude and 68°7' to 97°25' east longitude **[MNRE, JLNNSM Phase II, 2012].Fig 2.1.1 (b)** shows the Indian states with annual average direct normal irradiance which is around 4-5 KWh/m^2/Day. This much amount of solar energy is capable to produce 6,081,709 TWh/year, which can put India in the list of top 5 countries worldwide **[U.S Department of Energy. Open data catlog; 2016].**

2.2.2 Wind

India started developing wind power in early 1990's. In 2009-10, India's burgeoning rate in this sector was the highest amongest the top 4 nations worldwide. India is planning to generate around 100 MW of electricity from the offshore wind power plant in the coast of Gujarat (2014).

India also estimated to gain the total installed capacity of around 27300 MW from the wind capacity by the year 2017 and also 38,500 MW by the year 2022 **[http://www.mnre.gov.in/; Ministry of new and renewable energy, 2015].** According to the report of various organizations Though the various states have potential sites for Wind energy generation but to large extent following Indian states are the leading ones as shown below in the **Table 2.1.2(b).**

Table 2.1.2(b) State wise Wind energy development in India in 2015

S.No	States	Power(MW)
1	Tamil Nadu	4900
2	Maharashtra	2077
3	Gujarat	1863
4	Rajasthan	1088
5	Karnataka	1472
6	Madhya Pradesh	230
Total		11,800

To enhance power generation from wind energy a Centre for Wind Energy Technology(C-WET) has been set up by The government of India . This is with the sole purpose of getting an official approximation for the new project that could drive India forward in this sector. India's future in this sector seems very bright and secure and this is not only due to the accessibility of suitable sites but also due to effective ways of utilizing it.

2.2.3 Hydro

Hydro power is another renewable energy resource because of its source i.e natural water which is used to generate electricity. India has got abundant of hydro-electric potential and on global scenario India stands at fifth position in terms of harnessing hydro electric potential **[Sarkar P et. al, 2014].** An estimated hydro electric potential of Country is in impressive figure of 150,000 MW

[Jain SV,PatelRN, 2014]; Another estimate on September 30,2013 gave the current installed capacity of 39,788.40 MW, that accounts for the 17.39% of the total electric power generation in India **[Kumar D, Katoch SS; 2014].**

In India, hydro project which have 25 MW of capacity of electricity generation has been designated as Small Hydro Power projects. Further, Small hydro power projects are divided as Micro hydro plants which have capacity to generate 100 kW of electricity while Mini hydro plants have the capacity of ranging from 101 KW to 2000 KW. Around 6474 potential sites have been identified by The Government of India for SHP projects which are having a total capacity of 19,749 MW which will meet the power requirements of high altitude areas, where the electrical transmission grid system's supply is uneconomical. Out of the total capacity nearly half of the total potential lies with the states like Uttarakhand, Jammu & Kashmir , Himachal Pradesh and Arunachal Pradesh.

2.2.4 Biomass

Plants produce the organic matter which is termed as Biomass (both terrestrial, aquatic and their derivatives) which is a product of natural resources such as land, water, air and solar energy which possesses an enormous potential as a non conventional source of energy or a renewable source of energy. The plant uses solar energy from Sun to convert the surrounding CO_2 to sugars during the process called photosynthesis. Biomass obtained from plants upon combustion, releases energy in form of sugars is converted back to CO_2. The energy procured is thus exploited and liberated in a short span outline making the biomass as a fit wellspring of sustainable power source. The energy extent released through the combustion operation depends on many factors like environmental, chemical, thermal conditions etc. **[Vassilev SV et.al 2012, Obernberger I, Thek G 2004].** Many technological ways are accessible to change this unused into useful vitality assets, for example, biodiesel, electric power, ethanol, and plastics e.g biomass can be changed over to give an electric power source to vehicles.

2.2.5 Geothermal Energy

Scientists are working hard to find environment friendly, cost efficient, renewable and sustainable source of energy. One such potential lies with geothermal energy. Electricity can also be generated efficiently by using hot water lying deep inside the earth that can also be used to heat our homes. This energy is obtained from the natural heat of earth that creates geothermal energy. India possesses a great potential in becoming a leader in geothermal derived power generation. I n the upcoming years it is estimated that Geothermal energy would account for about 6.5% of total electricity ge neration in the world and India will have a major role in the years to come in this sector . Around 10000 MW of power generation by Geothermal energy has been estimated by Geological survey of India. Geothermal energy is expected to generate 10-20% of the world's energy need by the year 2050**.** Around 340 Geothermal hot springs destinations have been recognized in the nation by The Geological Survey of India. Many are in 500C-150°C temperature go which can be utilized for applications like direct warming and power age. Some of the well known geothermal sites are in the states such as Jammu Kashmir (J & K) , Himachal Pradesh (HP), Maharashtra and Uttarakhand and a newly discovered location of Tattapani in Chhattisgarh. Besides this Gujarat has setup to tap geothermal energy through Cambay between the rivers Narmada and Tapi.

III. SCOPE OF RENEWABLE ENERGY IN INDIA

During last so many year efforts of Government of India has yielded some impressive results, thus the increasing the offer of sustainable power source. It is calculated that the total share of energy generated by renewable energy resources would be 15.9% by 2022. Due to high sensitive concern for weather and many International climate conventions such as the United Nations Frame work on Climate Change UNFCCC, developed nations are promoting clean energy technologies.

Depletion in energy imports , decreasing the energy demand and supply gap and giving energy access to most of the people and giving services like solar lanterns and cooking systems (biogas plants) are some of the reasons for developing countries to advocate renewable energy. Sustainable power source can diminish the reliance on non-renewable energy sources and can make a huge commitment in decreasing their utilization which is so significant from vitality securityview point **[NSSO-Energy Statistics 2013].**

3. 1. Contribution of Agriculture waste for energy production.

On 2, November 2016, the news with the headline "Farmers' Unchecked Crop Burning Fuels India's Air Pollution" **was published in New York Times, the same impact news was published on 4, November, 2016 in Indian Express by title** "Ascend in contamination in Delhi due to edit consuming in neighboring states: Satyendra Jain", "Harvest consuming in Punjab, Haryana and Uttar Pradesh is the greatest patron in the ascent of contamination levels." said Delhi Health Minister Satyendra Jain. During stubble burning season a farm usually set ablaze at every single second. The effects of this kind of fire are not limited to Punjab and Haryana. Particulates which move to Delhi due to carried away by westerly winds cause several harmful health issues amongst people.

A study **under the title of "Delhi chokes on smoke from neighbouring states",** was conducted by IIT Kanpur which made the stubble burning responsible by considering it as third significant supporter of Delhi's winter air-contamination a part from construction site dust and smoke from vehicles . Stubble is nothing but a 8 to 10 inches of straw that remains behind after paddy during the harvesting of wheat and other crops by machine. To prepare the field to grow the next crop during the next sowing seasons, farmers usually burn the stubble. As per the same evaluation 550 millions tones of stubble is produced by India every year with highest contributor are from Uttar Pradesh, Punjab and Haryana states. An evaluation conducted in 2012 revealed the surprised stats that the states like Uttar Pradesh burnt 25% and Punjab & Haryana burnt 80% of rice residue.

IV. HEALTH IMPACT DUE TO BURNING STUBBLE

- Particulate matter 10 and 2.5 (PM): Eye burning sensation , bronchitis, heart related problems , causes cancer
- Carbon Dioxide (CO_2): Fast breathing rate , sudden rise in heart breathing rate
- Methane (CH_4): Choking of wind pipe that may lead to suffocation, headaches.
- Carbon Monoxide (CO): Can cause death , heart attacks
- Nitrogen Di Oxide (NO_x): Cough, chest pain, difficulty in breathing
- Sulphur Trioxide (SO_2): Eye burning sensation, chest problems, asthma related issues.

R. Sindhu et al (2016) have evaluationed the bio conversion process of sugarcane and other crops' residue to value added products. Sugarcane, rice and wheat are the major crops grown in India and stubble left after harvesting can be used for several useful chemicals production. Like the sugarcane bagasse which after fermentation acts as an excellent substrate for the production of various bio chemicals and enzymes. Now major concern is how well these residues can be utilized for the bio fuel production

Research Gaps

- From the literature it is found that there is need of a hybrid renewable energy model for rural electrification but its extensive exploration for its optimal sizing with least cost have to be find out.
- The production of energy based on the agricultural waste are on the research level only & no area have been identified in India for using the agricultural waste for the energy production.

V. RESEARCH PROCESS

The research process consists of three steps:

At first step literature evaluation identifies the problem. This step involves stages of revision of the real idea until gaps are identified with in the research interest area.

In second step as per the result of the first step, a suitable conceptual model is adopted to justify the sustainability issues regarding Renewable energy sector. Then performance measurement factors for that model are examined and validated by a panel of experts for suggestions and amendments.

Finally during the third and being a last step of the research, the proposed conceptual model/framework is applied in Renewable energy sector. The data collection involving a qualitative & quantitative outlook is exercised using in depth interview, examining energy based sector as the main data gathering method.

REFERENCES:

1. Azadian F, Radzi MAM. A general outlook toward building integrated photo voltaic systems and its implementation barriers: a evaluation. Renew Sustain Energy Rev 2013; 22:527–38. [11]
2. A Sustainable Development Frame work for India's Climate Policy, interim report, Center of Science Technology and Policy; January, 2015.
3. CEA, load Generation Balance report 2014 – 15.
4. Energy Statistics 2014, Central statistics office. New Delhi, India: Ministry of Statistics and Programme Implementation; 2014 [6]
5. Garg P. Energy Scenario and Vision 2020 in India. J Sustain Energy Environment 2012; 3:7–17. [3]
6. http://www.mnre.gov.in/; Ministry of new and renewable energy, 2015 [accessed on 29.6.2015].
7. IEA. Renewable information. Paris: International Energy Agency; 2013[15]
8. Indian Electricity Scenario 2015, Ministry of Power, Govt. of India, Available <http://www.powermin.nic.in> [accessed 28.07.15].
9. Indian petroleum and natural gas statistics 2013–14.Government of India, Ministry of Petroleum and Natural Gas Economics and Statistics Division, New Delhi. [21
10. Indian Renewable Energy and Energy Efficiency Database (IREED). Ministry of New and Renewable Energy, Government of India; Accessed on October 06, 2015.
11. India Solar Handbook, Bridge to India, April 2016
12. Jain SV, Patel RN. Inspections on pump running in turbine mode: are view of the state of the art. Renew Sustain Energy Rev 2014; 30:841-68. [24]
13. Kannan Govindan, Madan Shankar (2016),"Evaluating the essential barrier to off-shore wind energy an Indian perspective", International Journal of Energy Sector Management, Vol. 10 Iss 2 pp. 266 -282.
14. Kumar A, Kumar K, Kaushik N, Sharma S, Mishra S. Renewable energy in India: current status and future potentials. Renew Sustain Energy Rev 2010; 14: 2434–42. [13]
15. Kumar D, Katoch SS. Sustainability indicators for run of the river (RoR) hydro power projects in hydro rich regions of India. Renew Sustain Energy Rev 2014; 35:101-8. [25]
16. Ministry of New & Renewable Energy, GOI. Jawahar Lal Nehru National Solar Mission Phase II-Policy Document; December 2012. [30]
17. Mirza UK, Maroto – Valer MM, Ahmad N. Status and outlook of solar energy use in Pakistan. Renew Sustain Energy Rev 2003; 7: 501-14. [4]
18. Muneer T, Asif M, Munawwar S. Sustainable production of solar electricity with particular reference to the Indian economy. Renew Sustain Energy Rev 2005; 9(5): 444.
19. Natural gas as a pillar of growth: domestic production and import vulnerabilities, Council on Energy, Environment and Water, New Delhi; India, 2014: <http://ceew.in/pdf/CEEW-Natural-Gas % 28 India %29-Fact-Sheet-6June14.pdf>.
20. NSSO—Energy Statistics 2013, Central Statistics Office, Ministry Of Statistics And Programme

Implementation (MOSPI), Government Of India, New Delhi, www.mopsi.nic.in,
21. Obernberger I, Thek G. Physical characterization and chemical composition of densified biomass fuels with regard to their combustion behavior. Biomass Bio energy 2004; 27(6):653–69.
22. Owusu & Asumadu-Sarkodie, Cogent Engineering (2016), 3: 1167990
23. Panwar, N. L., Kaushik, S. C., & Kothari, S. (2011). Role of renewable energy sources in environmental protection: A evaluation. Renewable and Sustainable Energy Evaluations, 15(3), 1513–1524.
24. Pegels A. Renewable energy in South Africa: Potentials, barriers and options for support. Energy Policy 2010; 38: 4945-54. [16]
25. Renewable energy sources and climate change mitigation: Special report of the intergovernmental panel on climate change by O Edenhofer, R Pichs-Madruga, Y Sokona, K Seyboth (2011).
26. Sahoo SK. Renewable and sustainable energy evaluations solar photo voltaic energy progress in India: are view. Renew Sustain Energy Rev 2016; 59: 927-39. [1]
27. Sanjeev H. Kulkarni, Bhairu J. Jirage & T.R. Anil (2017) Alternative Energy Options for India -A Multi-criteria Decision exploration to Rank Energy Alternatives using Analytic Hierarchy Process and Fuzzy Logic with an Emphasis to Distributed Generation, Distributed Generation & Alternative Energy Journal, 32:2, 29-55
28. Sarkar P, Sharma B, Malik U. Energy generation from grey water in high raised buildings: the case of India. Renew Energy 2014; 69:284-9. [23]
29. Timilsina GR, Kurdgelashvili L, Narbel PA. A evaluation of solar energy: markets, economics and policies, vol. 2011, World Bank Policy Research Working Paper Series; 2011 [17]
30. U.S Department of Energy. Open data catalog; 2016. Available from:<http://en.openei.org/doe-opendata/dataset/solar-resources-by-class-and-country/resource/3e72f32a-7de1-4e5d-a25a 76928769625f>. [Last accessed 24 September 2016].
31. Vassilev SV, Baxter D, Andersen LK, Vassileva CG, Morgan TJ. An outline of the organic and inorganic phase composition of biomass. Fuel 2012; 94:1-33.
32. Veeraboina P, Ratnam GY. Exploration of the opportunities and challenges of solar water heating system (SWHS) in India: estimates from the energy audit & evaluation. Renew Sustain Energy Rev 2012; 16:668–76. [12]
33. Wee H-M, Yang W-H, Chou C-W, Padilan MV. Renewable energy supply chains, performance, application barriers, and strategies for further development, Renew Sustain Energy Rev 2012; 16:54, 51-65.

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